1951 BIENNIAL
INSPECTION
Sleeman

7- by 10-Foot Tunnels Program

Talk No. 1 - Controls and Dynamic Stability

(To be given in test chamber of high speed tunnel)

Speakers WC Sleeman, WB Kemp Jr, JW Paulson, LR Fisher

Introduction to 1st Group

Gentlemen, on your way in through the shop you probably noticed the models on display. These models are representative of those used in the various wind tunnels of the Stability Research Division. You are now in the test chamber of the high speed 7- by 10-foot wind tunnel which is one of the facilities of this Division.

Introduction to 2nd Group

Gentlemen, this room is the test chamber of the high speed 7- by 10-foot wind tunnel.

We will discuss briefly some of the problems confronting designers of high-speed aircraft, relating to the design of controls and attainment of adequate dynamic stability at transonic speeds.

The first chart illustrates some lateral-control configurations for unswept, swept back, and triangular wings. These controls appear promising because they have been found to retain their effectiveness at transonic speeds, provided the wings are kept reasonably thin. The familiar aileron and spoiler controls which normally are located near the tips of unswept wings are found to be most efficient for swept wings when located farther inboard. Other possible arrangements for swept wings include an all-moving tip control and a trailing-edge tip control of the type shown at the right. For triangular wings, consideration is being given to the conventional trailing-edge control, an all-moving tip control, and a tip control hinged on a skewed axis.

In attempting to provide moderate control forces, to be handled either manually or by power boost, the designer is confronted with a control-balancing problem common to all of the configurations illustrated, with the possible exception of the spoiler controls. The general nature of this balancing problem is illustrated in the next chart. This chart shows the control force, associated with the aerodynamic hinge moment at a constant deflection, plotted against Mach number for controls having simple balances. This line shows the allowable force limit for manual operation. Curves are shown for a plain (or unbalanced) flap, an inset-hinge flap, and an all-moving tip control. The latter two are assumed to be hinged in such a manner as to provide complete balance at low subsonic speeds. Notice that the control force for these flap arrangements increases rather abruptly in the transonic speed range. This abrupt change in force results from a change in flap chordwise load distribution from the subsonic (or nearly triangular) shape to the supersonic shape, which tends toward a rectangular form. This change in load distribution which can be interpreted as a rearward shift in center of pressure will generally persist regardless of the means used to obtain aerodynamic balance. Preliminary results indicate that the familiar inset-hinge control does not provide balance in the supersonic range. Some reduction in control force at supersonic speeds may be gained through use of an all-movable tip control, hinged to provide complete balance at low speeds. The forces at supersonic speeds still would be many times higher than the allowable limit for manual operation. The force variation illustrated for the tip control is representative of that obtained for several balanced controls, including flap-type controls with geared tabs, horn balances, or paddle balances. Although controls that exhibit this type of force variation may not be suitable for manual operation, they can be used advantageously in connection with an irreversible system employing a power boost. For such a system, the control could be designed to permit overbalance at low speeds, in order to reduce the power requirement of the boost at supersonic speeds.

If manual control is desired, it appears that a more complex type of balance must be used. One possible device might be as illustrated by this model, which combines a spring tab with some fixed aerodynamic balance, in this case, a paddle balance. Another possibility is illustrated by this second model. This involves linking the pilots control to a semaphore-type spoiler. Drag on the deflected spoiler causes it to rotate backwards, which, through gearing, transmits rotation to the aileron. This particular arrangement represents a servo-type of control, for which the pilot is required to provide only the force necessary to project the spoiler into the airstream.

In concluding the discussion of controls, it is apparent that more research is needed on unconventional control arrangements such as these models, and others, to provide effective controls requiring moderate forces at transonic speeds. ¶ An important phase of aircraft stability is concerned with the longitudinal and lateral oscillations following a disturbance. A longitudinal oscillation, for example, will be damped if the oscillation dies out. If the oscillation builds up it is undamped.

Many present-day high speed airplanes are experiencing difficulties with undamped oscillations at transonic speeds. The problem of damping the oscillations of these aircraft is becoming more severe as wing loadings increase and the aircraft fly at high altitude.

The next chart summarizes some results on damping in pitch for several model configurations at transonic speeds. The damping in pitch coefficient is plotted against Mach number. Damping coefficients in this region indicate that the longitudinal oscillation will be damped and coefficients in this region indicate an undamped oscillation. These results were obtained from tests of free flight rocket models by the Pilotless Aircraft Research Division. The curve for the triangular wing model with 45° leading edge sweep, however, was obtained from wind tunnel tests and had been presented by the Ames Laboratory during the inspection held last year. This model showed unstable oscillations at Mach numbers near 1.0. The triangular wing model with 60° sweep, however, showed no loss in damping in this region. These results indicate that adequate damping of the longitudinal oscillations of tailless triangular wing airplanes may be attained provided the wings are thin and have sufficient sweep. The unswept wing and fuselage combination also showed instability near a Mach number of 1.0. It was possible, however, to obtain stability through the speed range by addition of a tail, thus overcoming the inherently poor damping characteristics of the unswept wing.

We would now like to demonstrate some of the equipment used in the high-speed 7- by 10-foot wind tunnel for investigating dynamic characteristics of airplanes. This model was used to study the build up of rolling moment following an abrupt deflection of the spoiler control. You may step into the test section, by way of the large door at your left to witness the demonstration.

<u>Side Wall</u>

This model illustrates the technique used for measuring damping in pitch. The rate of decay of the oscillation of the model is measured and is an indication of the damping in pitch.

<u>Sting</u>

The model on the sting in the center of the tunnel is used to determine the aerodynamic forces on aircraft configurations during a rolling motion. The operator will now roll the model. The model is driven by a hydraulic motor located in the sting support. The forces and moments on the model are measured by a six-component strain-gage balance contained within the model. The apparent eccentricity of rotation is caused by this bent sting which provides for an angle of attack of the model while still allowing the model to rotate about its center of gravity. Of course during testing, only one of these models would be mounted in the tunnel at a given time. This concludes our demonstration.

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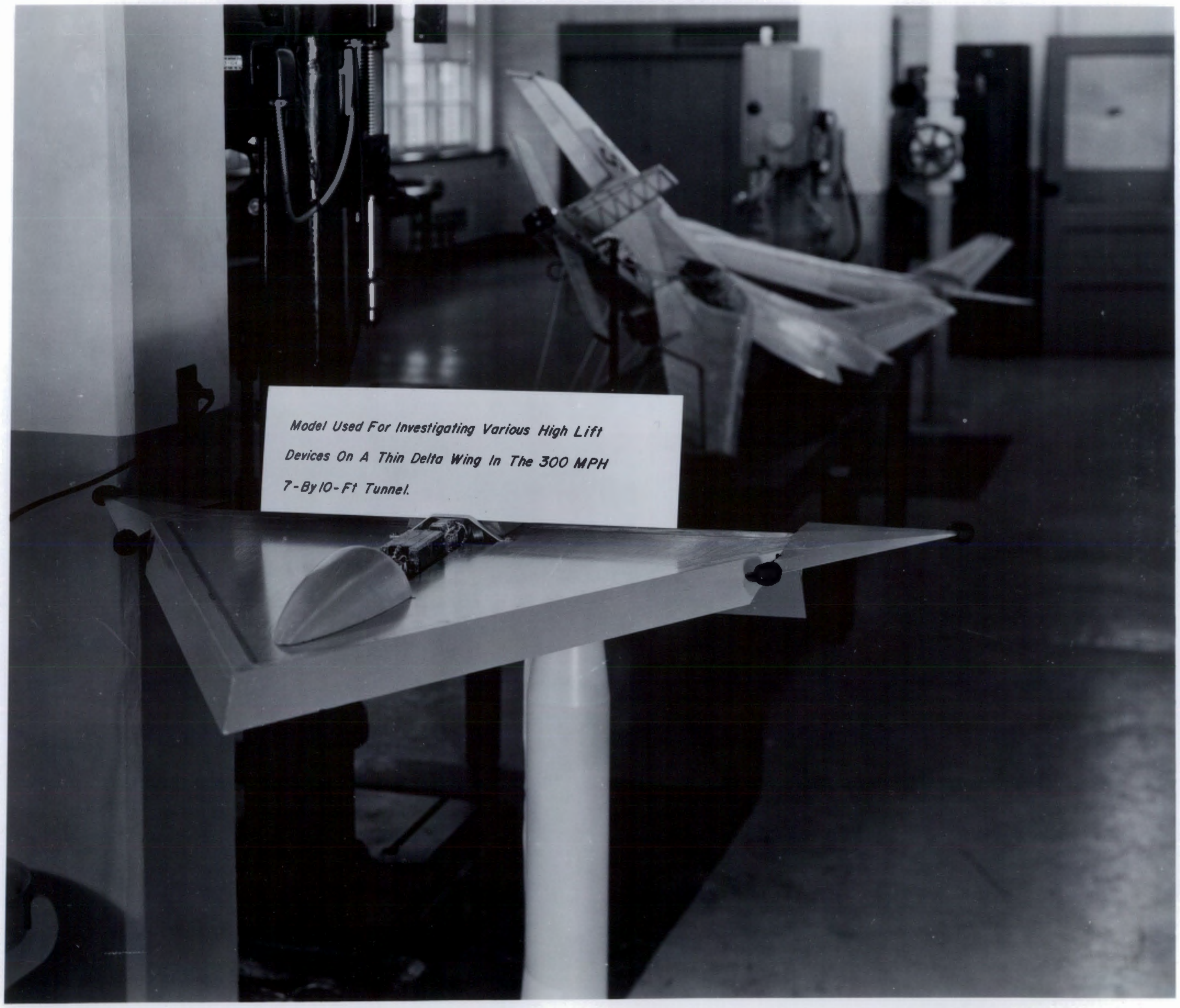

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Model Used in the 300 MPH 7-by-10 Foot Tunnel to Investigate the Effects of Wing Flexibility on the Stability and Control of Airplanes.

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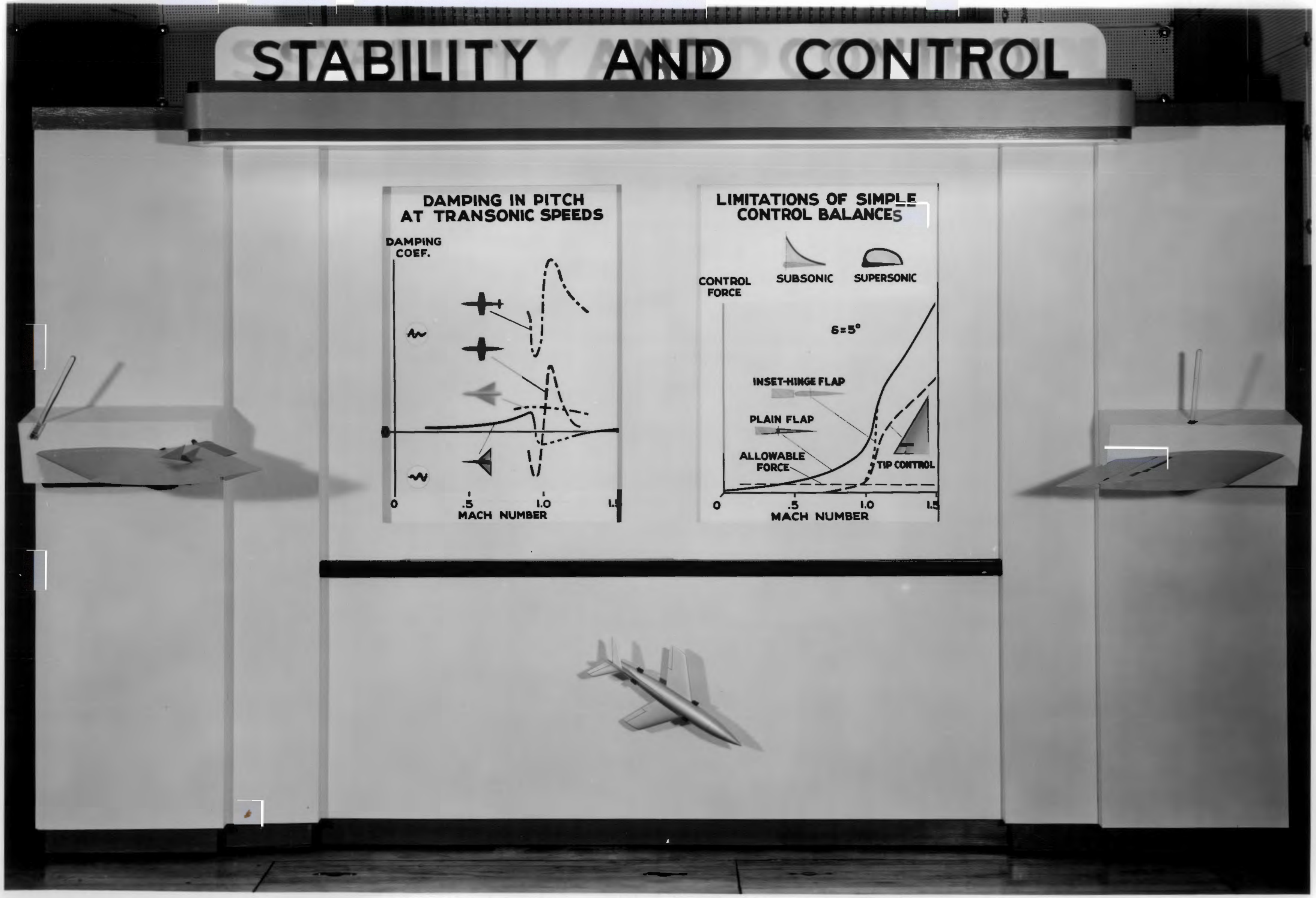

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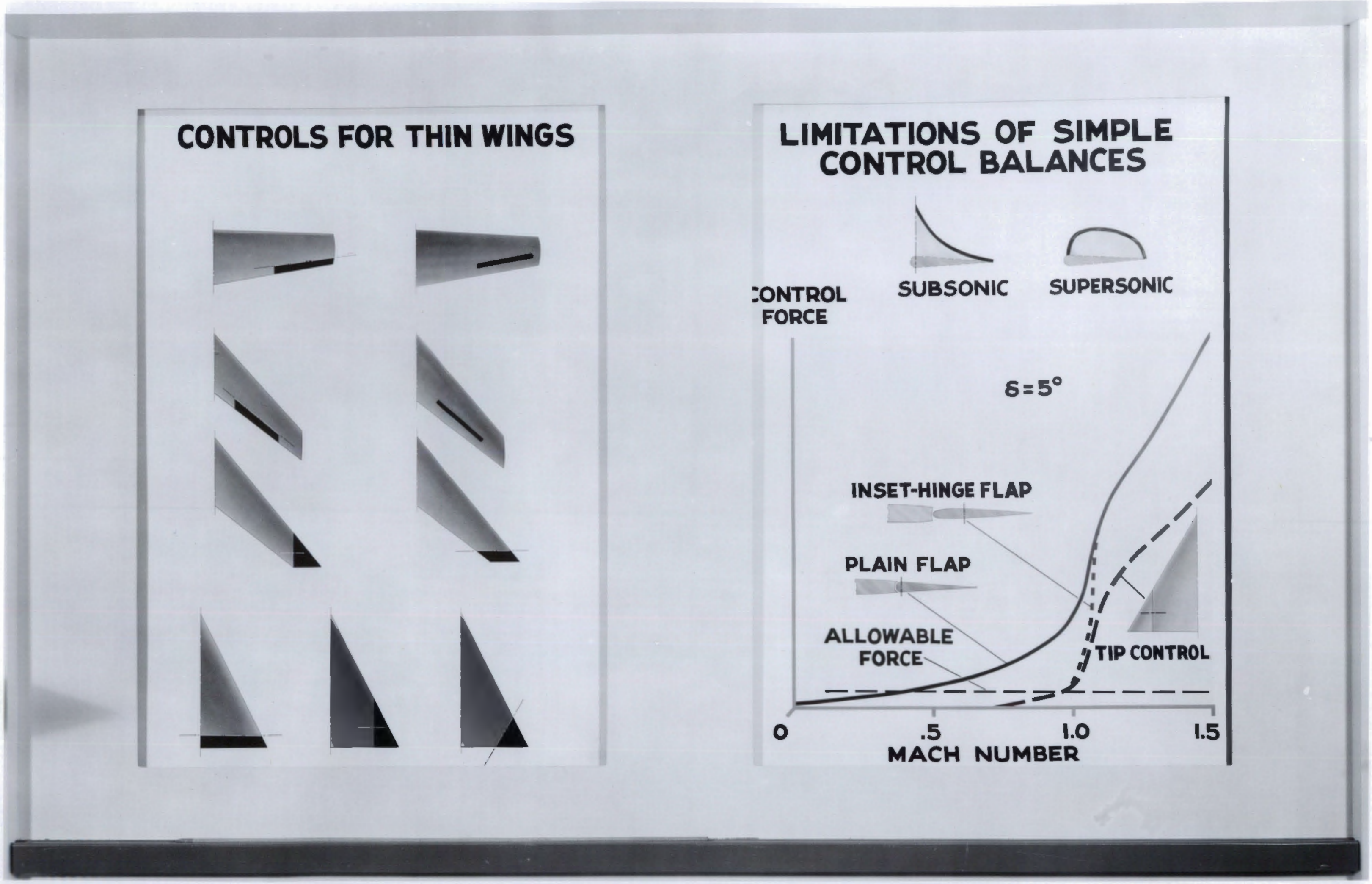

CONTROLS FOR THIN WINGS

LIMITATIONS OF SIMPLE CONTROL BALANCES

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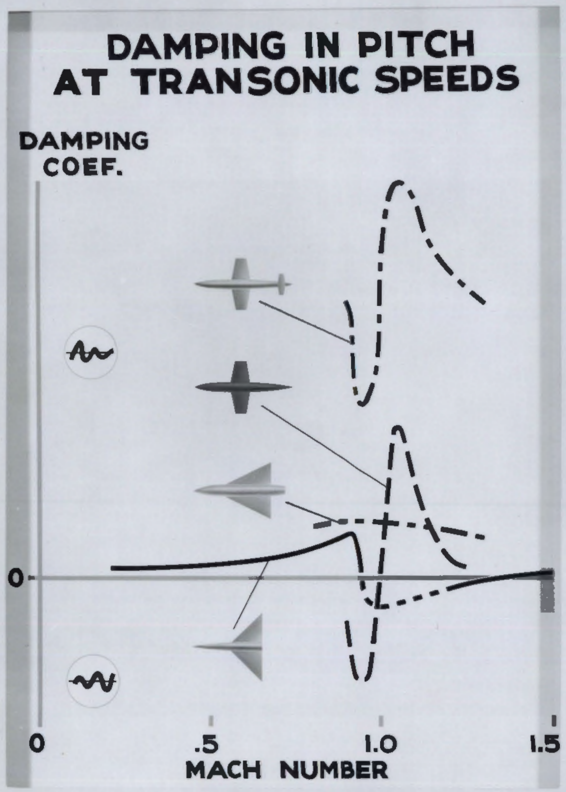
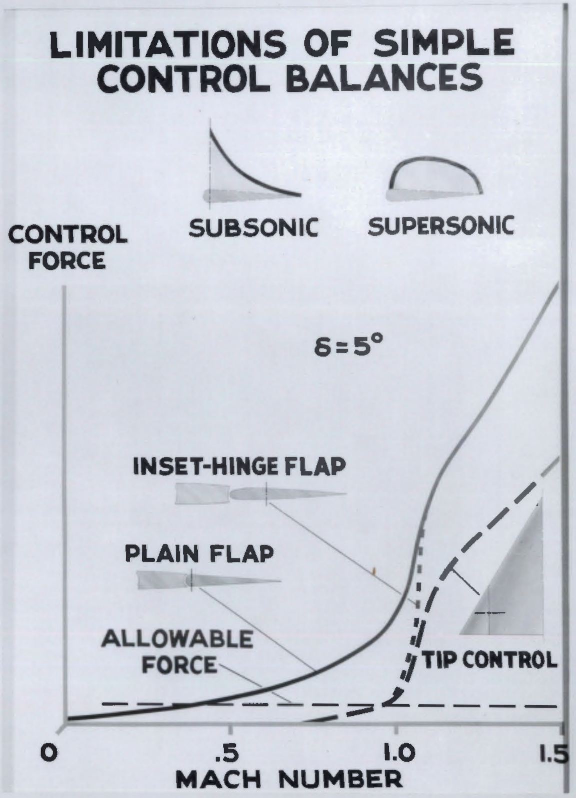


DAMPING IN PITCH AT TRANSONIC SPEEDS



LIMITATIONS OF SIMPLE CONTROL BALANCES

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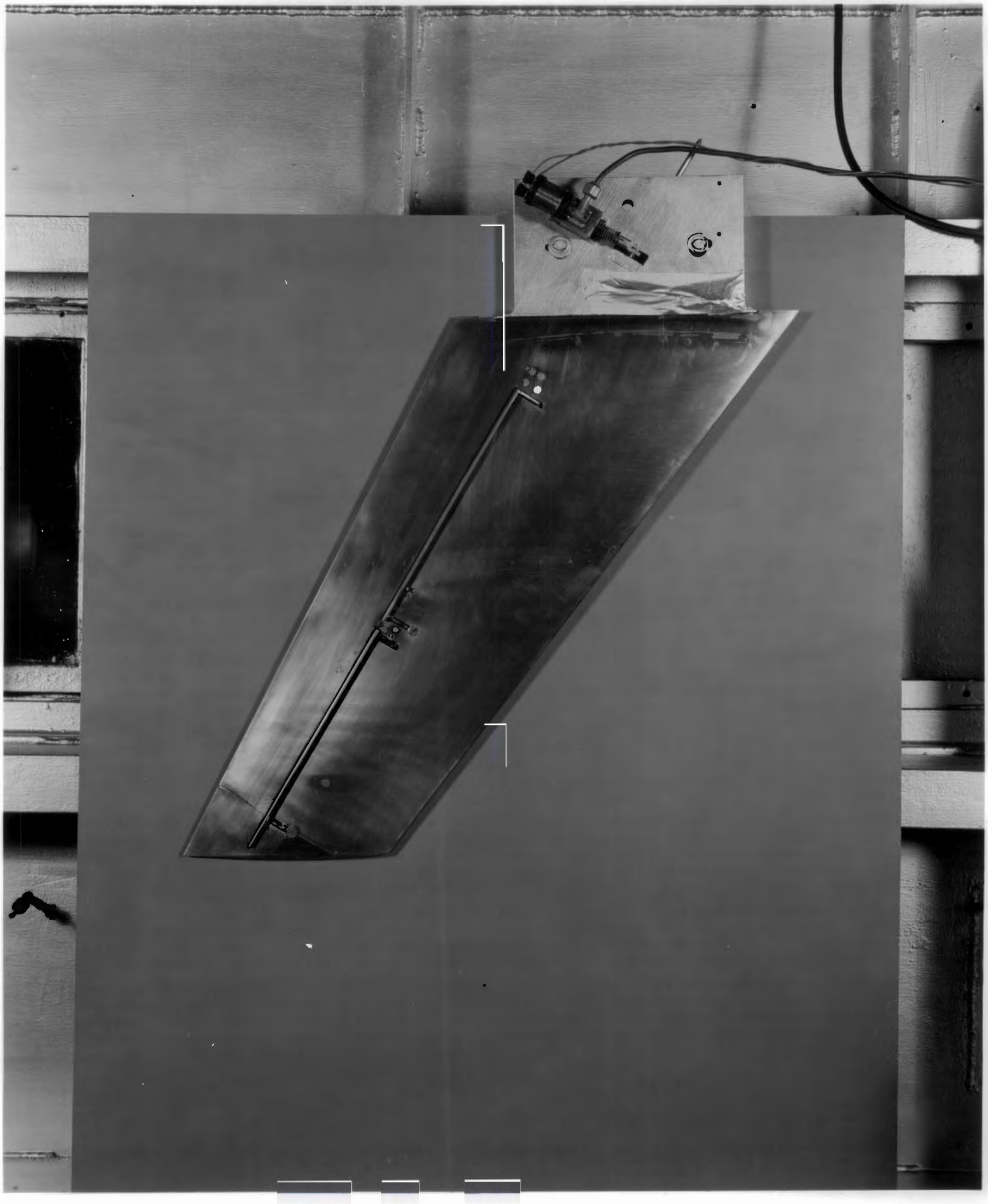

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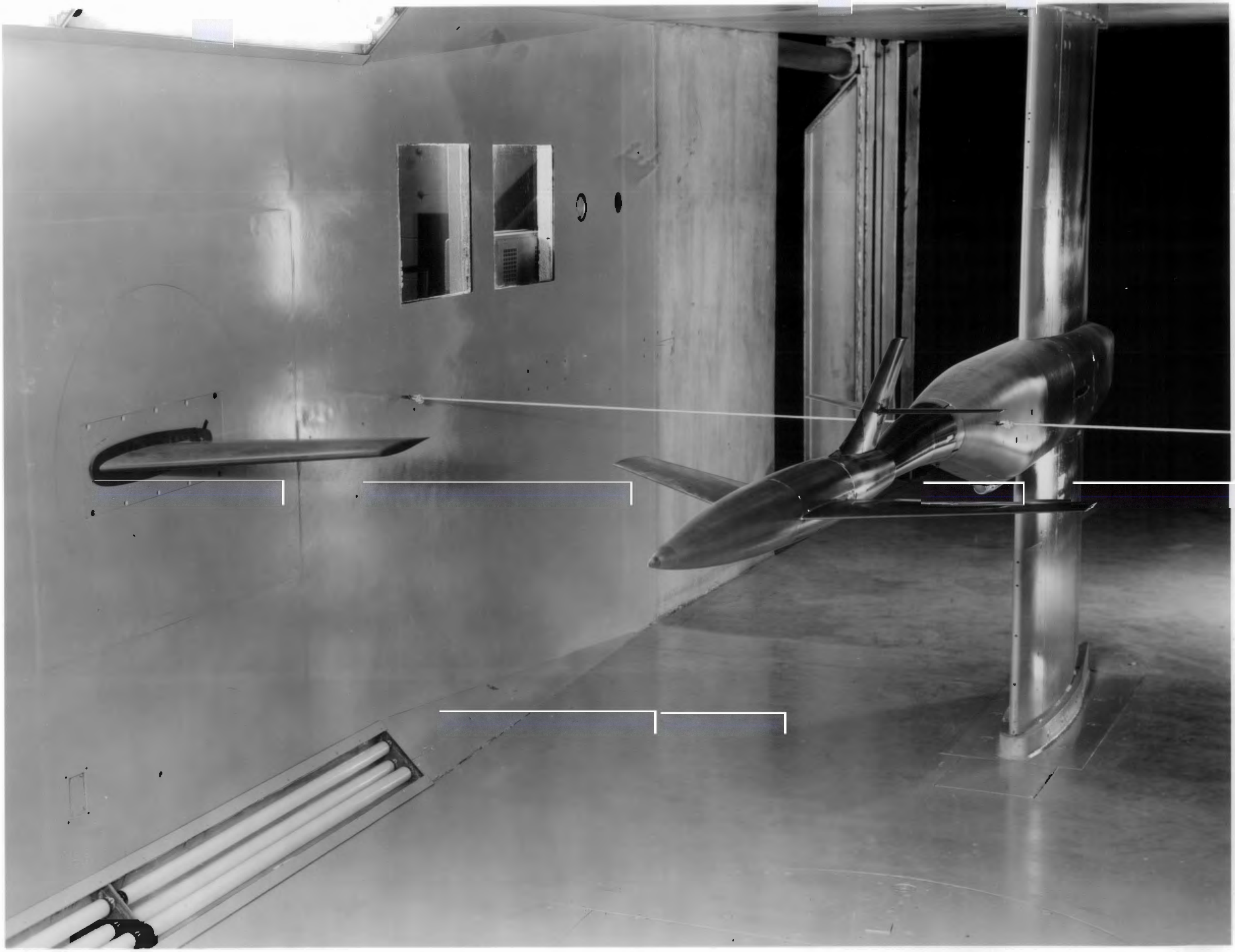

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7- By 10-Foot Tunnels Program

Talk No. 2 - Flow Field Studies with Tuft Grid

(To be given in test chamber of 300 MPH tunnel)

Speakers DR Riley, SH Scher, FS Malvestuto Jr, RL Naeseth

INTRODUCTION A

Gentlemen, before entering this room you passed through the shop, where you probably noticed a number of wind-tunnel models on display. These models are representative of the types used in the various wind tunnels of the Stability Research Division. The room in which you are now located is the test chamber of the 300 mile per hour 7- by 10-foot wind tunnel, which is one of the facilities of this Division.

INTRODUCTION B

Gentlemen, this room is the test chamber of the 300 mile per hour 7- by 10-foot wind tunnel.

One of the aerodynamic problems studied here concerns the interference between the various component parts of aircraft. The wing of an airplane, for example, leaves behind it a field of disturbance which alters the flow conditions in the region normally occupied by the tail. This chart simply represents an artist's conception of the wake portion of the flow field; actually, the entire flow field is much more complex and can not be represented by such a simple illustration. For wings having high aspect ratios, the effect of the flow field at the tail generally does not present a serious problem, since the disturbances leaving the wing tips are far apart and therefore the tail may move considerable distances, either vertically or laterally without encountering severe gradients in downwash or sidewash angles. When a tail assembly is used behind a low-aspect-ratio wing, however, the problem is considerably more complicated, since the highly disturbed regions, leaving the wing tips, lie close to the tail and therefore the tail may encounter severe changes in flow angularity even for small tail movements. This condition affects not only the static stability of the airplane but also the damping of oscillatory motions. The influence of the flow field on longitudinal stability can be largely avoided of course, if no horizontal tail is used. Problems associated with vertical stabilizing surfaces still exist, however, whether these surfaces are located on the fuselage, or attached to the wing.

I would like to discuss a very simple technique that recently has been developed for studying the flow behind a wing or any other airplane component. The set-up used in applying this technique is indicated on the next chart. This illustration represents a cut-away view of a portion of a wind tunnel showing the model mounted in the test section. Apparatus, which we call a tuft grid, is located behind the model. The grid consists simply of a steel framework on which fine wires are strung, both vertically and horizontally with woolen tufts attached to the wire intersections. When the tunnel is in operation, the air flows past the model and through the grid. At the same time, either still or motion pictures of the grid are taken by a camera located far downstream, while the attitude of the model is being changed. The next chart illustrates the information provided by a single picture. The camera picks up only the projections of the tufts and model in a vertical plane. The triangular shaped dark area on this chart for example represents a triangular-wing model at an angle of attack, as seen from the camera stationed far downstream; the base of the triangle representing the wing trailing edge. The various short dark lines represent the projections of the tufts. This one particular tuft has been magnified for the purpose of analysis. The vertical and horizontal projections are indications of the local downwash and sidewash angles of the flow. In the undisturbed regions, the tuft appears only as a small dot. We will now demonstrate by means of a short movie some flow studies made behind low-aspect-ratio wings in the Langley stability tunnel, where this technique was first developed.

The first pictures are for a rectangular wing having an aspect ratio of 2.61. The angle of attack is varied slowly from 0° to 24° while the yaw angle is held constant at zero. The solid white line that is apparent is the wing trailing edge and moves downward as the angle of attack is increased. The gray area immediately above the white line is the wing. Notice the formation of the trailing vortices at the wing tips and the increase in the flow angularity over the entire field. As the angle of attack is increased, the trailing vortices remain near the wing tips for this wing. The first evidence of stalling is near the wing center section.

The second set of pictures is for a 60° triangular wing of aspect ratio 2.31. The angle of attack is varied slowly from 0° to 34° while the yaw angle is held at zero. The trailing vortices again become evident first at the tips, but in this case they move inward as the angle of attack is increased. No abrupt evidence of stalling can be observed, since, for this wing the stall is progressive, being generated over a large range of angles of attack. Notice that a tail assembly located in about this position would be in a highly disturbed region, since the trailing vortices are very close.

In this third set of pictures a 60° triangular wing is oscillated in pitch. These pictures are for a one-cycle-per-second oscillation. Notice the relationship of the vortex pattern to the wing trailing edge and the effect of the oscillating wing on the flow field in general.

These pictures are for the same wing oscillating at four cycles per second. The wake pattern indicated by the grid appears to be somewhat out of phase with the model motion. Pitching oscillation studies such as these lead to a better understanding of the tail contribution to the longitudinal dynamic stability of complete airplane configurations.

The last pictures show the triangular wing model at an angle of attack and being oscillated in yaw. These pictures are for a one-cycle-per-second oscillation. In this case, the model is mounted inverted in the tunnel as a matter of convenience. Notice that for this oscillation the vortices are not distinct throughout the cycle.

In the four-cycle-per-second oscillation there are two vortices existing at all times. The discrepancy between the one- and four-cycle-per-second oscillations is usually referred to as a frequency effect. Yawing oscillations studies of this nature provide information on the tail contributions to the lateral dynamic stability of complete airplane configurations.

This concludes the moving pictures, however, we have a similar setup in the wind tunnel and it will be operated briefly. You may observe the wake pattern through the large door toward the rear, or you may look through the window in the side wall where you can see both the wake tufts and tufts attached to the upper surface of the wing.

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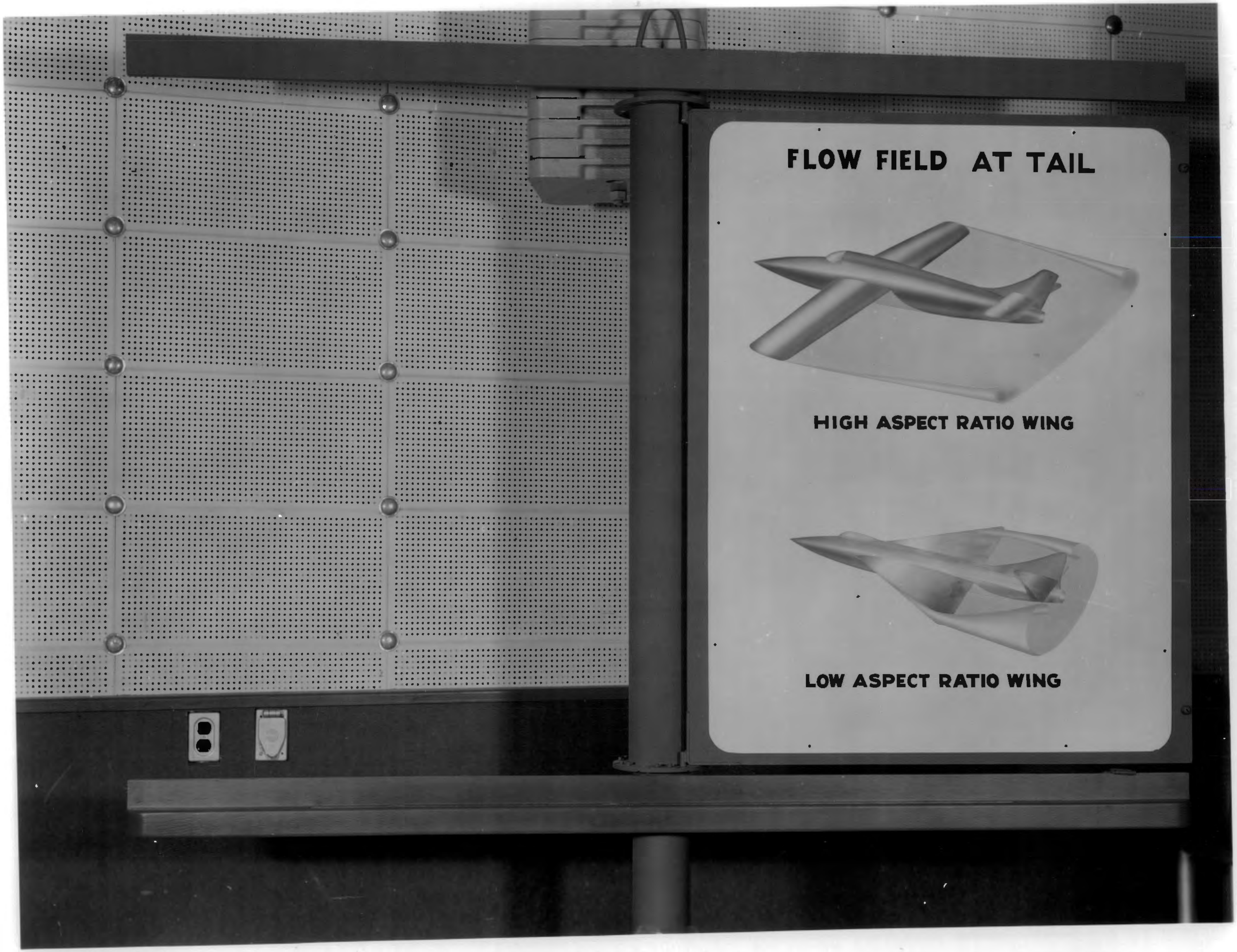
DEMONSTRATION

This concludes the demonstration. You may now cross the shop and enter the test chamber of the high-speed 7- by 10-foot tunnel where a second demonstration will be given.



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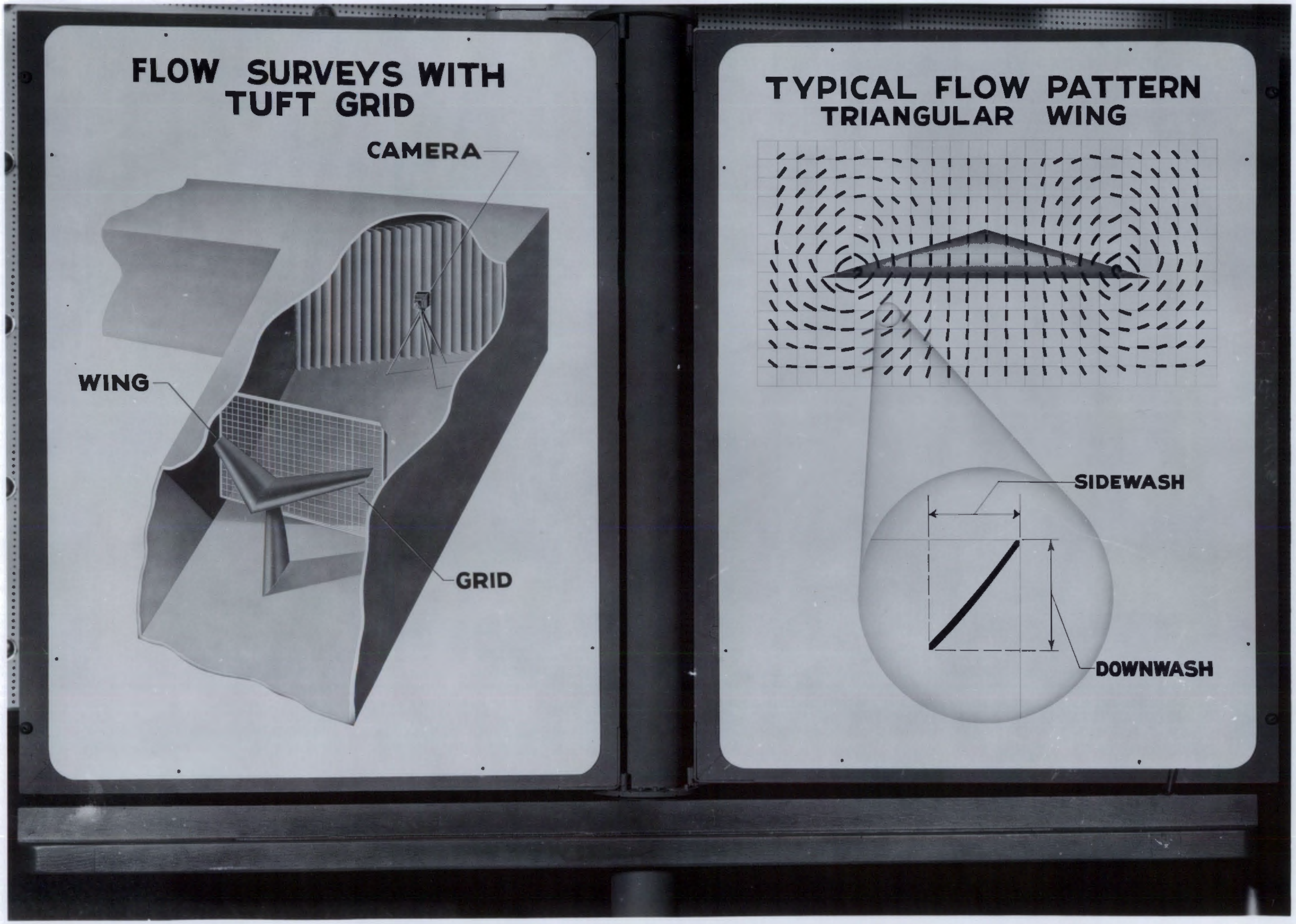
FLOW SURVEYS WITH TUFT GRID
CAMERA
WING
GRID
TYPICAL FLOW PATTERN
TRIANGULAR WING
SIDEWASH
DOWNWASH

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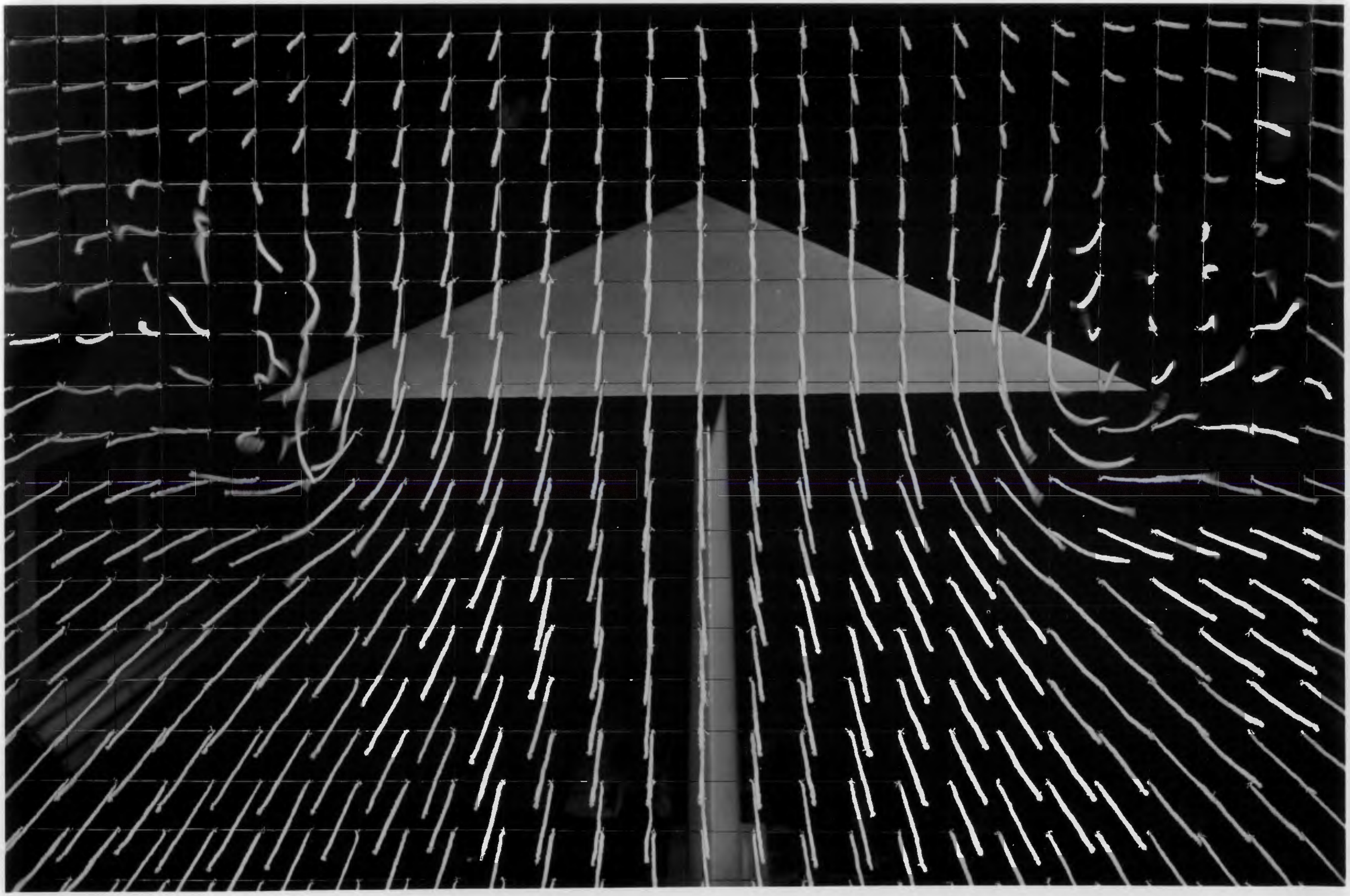

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